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# 11. Course Collaboration Models

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# Course Collaboration Models

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## 1 Introduction

Quantitative and Mathematics Support Centers (QMaSCs) come in many different shapes and sizes and the services they provide are just as variable. Ranging from the most basic model of drop-in tutoring help for certain introductory math classes, to teaching and learning centers that provide assistance to course faculty at multiple points throughout the semester and in multiple disciplines. Options for course collaboration can include:

- Course placement and advising based on assessment administered and evaluated by QMaSC directors.
- Just-in-time course support with drop-in tutoring and online tutorials, including support for software packages (Mathematica, SPSS, Excel, etc.).
- Creation of ancillary materials to support and scaffold background quantitative and mathematical knowledge.
- Ongoing structured support in study groups and supplemental instruction including targeted workshops.
- Expert support of quantitative projects in non-quantitative fields, including in-class workshops and presentations on writing with numbers and database navigation.
- Follow-up assessment to measure outcomes at the course and institution level.

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## 2 Assessment

The topic of assessment might not seem to belong in a chapter on course collaboration models, but more and more QMaSCs are involved with the administration of quantitative and mathematical assessments and the subsequent evaluation of collected data. Many QMaSC directors share this information with faculty and advisors, and often participate in the accurate placement of students in courses. Likewise, directors funnel students with weak incoming skills into targeted support opportunities. Diagnostic tools include made-to-order instruments such as Accuplacer, and in-house creations that seek to assess algebra skills, calculus readiness, and overall quantitative reasoning (QR) abilities. Algebra skills and calculus readiness tests are straightforward to develop and are utilized at institutions of all sizes to accurately place students in appropriate algebra, pre-calculus and calculus courses. Relying on high school GPA is problematic, as variability in rigor in high schools throughout the country can lead to significant differences in interpreting high school preparation. Community colleges struggle to place students in the current “layer-cake of algebra dominated mathematics” [1]. As of Fall 2010, the developmental math programs at 2-year colleges centered upon algebra, in particular, 61% of all math enrollments consist of some form of algebra. This statistic is even higher given that 30% of 2-year schools have their pre-college level math programs offered outside of the math department in developmental (remedial) programs: Table 1: 2-year course enrollments, *note that 30% of developmental math programs at 2-year schools are outside of math departments and thus not listed here [2].

Table 1: 2-year course enrollments, *note that 30% of developmental math programs at 2-year schools are outside of math departments and thus not listed here (CBMS 2010) [2]

| Two-year College Course Enrollments ( in 1000’s) In Math* Courses | | | | | |
|---|---|---|---|---|---|
| | Pre-College Level | | | | |
| | **1990** | **1995** | **2000** | **2005** | **2010** |
| Pre-Algebra | 45 | 91 | 87 | 137 | 226 |
| Elementary Algebra (HS level) | 262 | 304 | 292 | 380 | 428 |
| Intermediate Algebra (HS level) | 261 | 263 | 255 | 336 | 344 |
| | Pre-Calculus Level | | | | |
| College Algebra | 153 | 186 | 173 | 206 | 230 |
| College Algebra + Trigonometry | 18 | 17 | 16 | 14 | 11 |
| **Total** | **1272** | **1425** | **1347** | **1696** | **2024** |

Theoretically, the justification for so much algebra is to prepare students for Calculus, despite the fact that quantitative reasoning (QR) courses are steadily increasing in number and attracting more and more students. Enrollments in Math for the Liberal Arts and Finite Math courses rose 63% from 1995 to 2010; whereas mainstream Calculus I enrollments rose only 20% over the same period [2]. The total enrollment in these two general education math courses exceeded mainstream

Calculus I enrollments 318,000 to 300,000 in fall 2010:

Table 2: 2-year course enrollments, *note that 30% of developmental math programs at 2-year schools are outside of math departments and thus not listed here (College Board of Mathematical Sciences (CBMS) 2010) [2]

| College Board of Mathematical Sciences 2010 Survey (Enrollments in 1,000's) | | | | |
|---|---|---|---|---|
| | **1995** | **2000** | **2005** | **2010** |
| Finite Math (2-year) | **24** | **19** | **22** | **18** |
| Liberal Arts Math (2-year) | **38** | **43** | **59** | **91** |
| Calculus I (2-year) | 58 | 53 | 51 | 65 |
| Finite Math (4-year) | **59** | **82** | **94** | **62** |
| Liberal Arts Math (4-year) | **74** | **86** | **123** | **147** |
| Calculus I (4-year) | 192 | 192 | 201 | 235 |

Similarly, enrollments in *Liberal Arts Math* courses, those most often designated as QR, went up 113% over this period. This movement of "math for everyone else" is in part a recognition that the majority of college students will not major in a Science, Technology, Engineering, or Math (STEM) field. Of the 1,303,050 college-ready students in Fall 2005 (from the 4,012,770 cohort of 2001 9th-graders) only 277,550 went on to major in STEM fields, and only 166,530 graduated with a STEM degree in May 2011 [7]. This illustrates why institutions are providing an increasing number of QR course offerings to their students. Colleges and universities strive to provide a mathematical experience that will directly benefit their students' QR abilities. This new emphasis requires assessment of both traditional algebra and Calculus readiness alongside assessment of QR. The latter is more problematic for QMaSC directors because QR is relatively new on the academic landscape and traditional college-readiness tests, like the SAT, are not designed for QR. The Mathematical Association of America's Special Interest Group in Quantitative Literacy (SIGMAA-QL) conducted a survey in 2009 of 1,554 institutions and found that while 87% of respondents had some form of quantitative requirement [8] only about 23% of them have pre-post assessment of quantitative literacy and reasoning (QLR) skills. Most of these internal assessment tools have no national norms with which to compare. Furthermore, the actual construct of "quantitatively literate" remains undeveloped [9]. A QLR test is available through a National Science Foundation (NSF) funded project, QLR Assessment (QLRA), in the Transforming Undergraduate Education in STEM (TUES) program. The QLRA project created a non-proprietary nationally normed, valid, reliable QLR test[1] , which was piloted at over 30 institutions across the country from 2-year schools to public universities and liberal arts colleges. To learn more about this assessment, contact the

[1] `http://serc.carleton.edu/qlra/index.html`

principal investigator, Eric Gaze (egaze@bowdoin.edu). The 2012 pilot data for this 23 question multiple-choice test shows a nice distribution with no ceiling or floor effects:

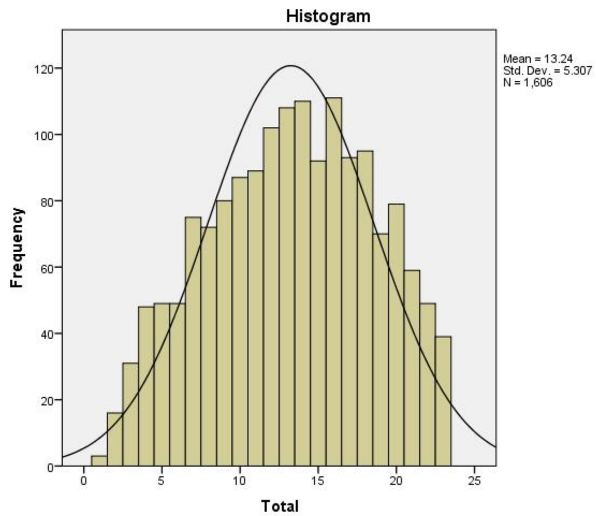


Figure 1: QLRA 2012 test data

Bowdoin College administers a QR test to all incoming students (initiated in 1995) and uses the scores for placement and advising purposes in all math and science courses. At Bowdoin, a student's Q-score is among the best predictors of GPA with the following correlation coefficients derived from 6 years of data (N $\sim$ 3,000):

- R = 0.39 Q-score vs. Overall GPA
- R = 0.48 Q-score vs. Math/Science GPA
- R = 0.48 Q-score vs. First year overall GPA

Accurate placement in math/science coursework is an incredibly important part of the QMaSC director's job. Before directors of QMaSCs can collaborate with the courses themselves, it is crucial that students be placed into the correct level giving them the best chance of a successful start. QMaSC directors are often concerned mainly with Calculus placements and the QLRA test may be a valuable part of this advising process, especially for students with no AP scores.

## 3 Tutoring and Study Groups

Once students have been placed into an appropriate math or science course, QMaSC directors will often develop and oversee a broad range of ongoing academic support activities. Drop-in tutoring for quantitative and mathematics courses is the most obvious way in which a QMaSC can support instruction. Directors and student tutors hold "office hours" in a dedicated tutoring space.

Students looking for help can either sign up for a block of time to work one-on-one with a tutor, or they can just drop-in to work collaboratively with tutors and other students. Course specific study groups, coordinated by the QMaSC director, provide another option for students seeking assistance. Working closely with course faculty, the director trains and assigns student tutors to lead the study groups. Study group leaders meet their assigned class at the start of the semester to introduce themselves and explain the purpose and value of attending study groups. The leader emphasizes the importance of forming regular study habits, developing academic peer support structures, and working productively under the guidance of trained peer tutors. Individualized attention is also available at many institutions with QMaSC directors coordinating individual tutorials. These arrangements for one-on-one tutoring provide students with a more private experience, which is especially helpful in cases of students with severe math anxiety or learning differences. QMaSC directors can also work with faculty to develop tutorials on specific math concepts for students in math and science courses. These tutorials can take the form of worksheets, workbooks, or online modules. The following list provides a subset of available resources on the internet that QMaSC directors may find useful in an attempt to avoid reinventing the wheel:

- Khan Academy: Definitely the giant in this arena and has expanded beyond simple math to almost all disciplines. `https://www.khanacademy.org/`
- Center of Math Organization: Great resource with lots of tutorials and digital materials. `http://www.centerofmath.org/`
- Hippocampus: Nice collection of different resources including video tutorials. `http://www.hippocampus.org/?gclid=CKK18vzPh7oCFUWd4AodxG8AZA`
- Cool Math: The name says it all, you can be the judge. `http://www.coolmath.com/algebra/`
- Math Planet: Videos and problems available. `http://www.mathplanet.com/`.
- Calculus Help: Fun problems in addition to online tutorials. `http://www.calculus-help.com/`

These "just-in-time" activities free up course faculty from spending valuable class time on review material. QMaSC directors can also create tailored assessments for course specific skills to identify weaknesses among students taking the course.

## 4 Workshops

QMaSC directors may find workshops to be particularly useful in providing supplemental support. The instructor of a science course that explores exponential growth can ask for a workshop on this topic led by either the director or a trained student tutor. Discipline specific content can also be reviewed using a similar format but led by student tutors who have previously and successfully completed the course. Workshops on the basics of logic or proof by induction can be offered for students in a Foundations of Mathematics course. In addition, a series of workshops can be designed to provide technological support for software packages being used in courses. For example, statistics instructors can request workshops on the use of R while mathematics instructors can request supplemental instruction in typesetting using LaTeX or in using programs such as Mathematica, Maple, MatLab, or SPSS. Likewise, instructors of humanities courses that use databases can request that the QMaSC director lead a class or workshop on working with data or writing with numbers. Follow-up instruction can then take place as needed using the QMaSC tutoring resources.

See the appendices for detailed examples of a calculus workshop designed for a physics class and a faculty development workshop on reasoning from evidence. These examples might be particularly useful for QMaSC directors when thinking about creating their own materials.

## 5 Conclusion

QMaSCs are more than just a place where students can go to get help factoring quadratics and integrating trigonometric functions. QMaSC directors are involved throughout the semester helping to place students in appropriate courses using well-developed assessment tools and providing supplemental instruction and tutoring to assist students as the course progresses. QMaSC directors can assist faculty with identifying weaknesses in students' background knowledge and coordinating resources to address such deficiencies. QMaSC directors can lead the campus community in an effort to incorporate QR across the curriculum, raising awareness for the value and utility of reasoning from all forms of evidence, including quantitative information. In the process QMaSC directors positively impact all shareholders on campus, from faculty and students in math and quantitative courses to the students who provide support as tutors and study group leaders.

## 6 Bibliography

[1] J. M. Shaughnessy, "Endless algebra the deadly pathway from high school mathematics to the college mathematics," February 2011. Accessed from `http://www.nctm.org/News-and-Calendar/Messages-from-the-President/Archive/J_-Michael-Shaughnessy/Endless-Algebra%E2%80%94the-Deadly-Pathway-from-High-School-Mathematics-to-College-Mathematics/` on June 28, 2016.

[2] Conference Board of Mathematical Sciences, "Statistical Abstract of Undergraduate Programs in the Mathematical Sciences in the United States," 2013.

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[4] B. Madison and L. A. Steen, "Evolution of numeracy and the national numeracy network," *Numeracy*, vol. 1, no. 1, 2008. Accessed from `http://services.bepress.com/numeracy/vol1/iss1/art2` on June 11, 2013.

[5] National Council of Teachers of Mathematics. Reston, VA: National Council of Teachers of Mathematics, 1989.

[6] L. Steen, *Why numbers count: Quantitative Literacy for Tomorrow's America.* New York, NY: The College Board, 1997.

[7] D. Kaplan, "The STEM Challenge," *Fortune*, June 14, 2010.

[8] M. Schield, "Quantitative graduation requirements at us four year colleges," 2010. Presented to the SIGMAA-QL board at the 2010 Joint Math Meetings.

[9] J. Bookman, S. Ganter, and R. Morgan, "Developing assessment methodologies for quantitative literacy: A formative study," *American Mathematical Monthly*, vol. 115, no. 10, pp. 911–929, 2008.

# 7 Appendix

**A. Calculus Workshop Designed for Use in Physics Course**

The following was created for a workshop on calculus in a physics class. The professor wanted to make sure students understood the "kinematic chain," an expression that is unfamiliar to many mathematicians. Kinematic chain refers to the relationship between the position, velocity and acceleration functions. In particular, students in the physics class were expected to be able to work backwards from graphs of acceleration to velocity and position. Discipline specific vocabulary and notation is often a huge stumbling block for students in transferring their knowledge in a math class to an applied domain. This workshop starts by reviewing basic concepts of the derivative and then moves on to discussing the kinematic chain, first using notation from a calculus class then comparing with the notation from physics.

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**Calculus Workshop on Kinematic Chain for Physics Class**

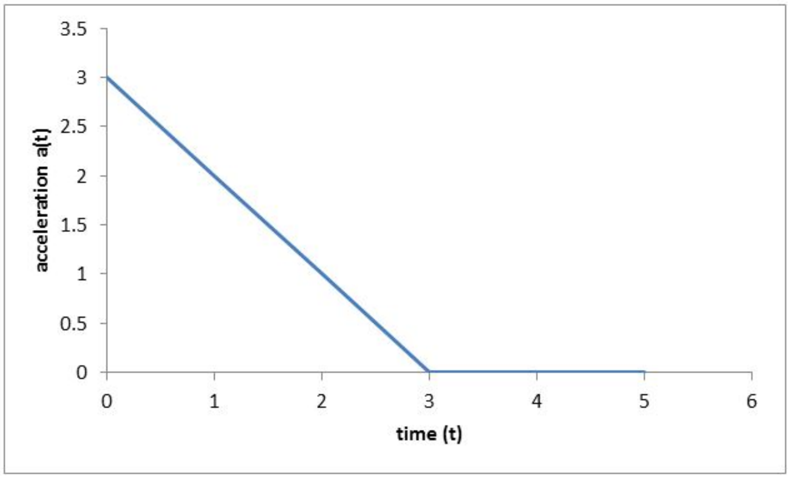
There is a fundamental relationship between the signs of the 1st and 2nd derivatives and the shape of the function. The function is **increasing/decreasing** when the 1st derivative is positive/negative, and **concave up/down** when the 2nd derivative is positive/negative. **Extrema** occur when the 1st derivative changes sign (zeroes) and **inflection points** occur when the 2nd derivative changes sign.

<table>
<tr><td>Intervals</td><td>. . . -5</td><td>-5 . . . 2</td><td>2 . . . 18</td><td>18 . . . 34</td><td>34. . . 57</td><td>57 . . .</td></tr>
<tr><td>1st derivative $f'(x)$ or $dy/dx$</td><td>**Positive (+)**</td><td>**Negative(-)**</td><td>**Negative(-)**</td><td>**Positive(+)**</td><td>**Positive (+)**</td><td>**Negative(-)**</td></tr>
<tr><td>2nd derivative $f''(x)$ or $d^2y/dx^2$</td><td>*Negative* (-)</td><td>*Negative*(-)</td><td>*Positive* (+)</td><td>*Positive* (+)</td><td>*Negative* (-)</td><td>*Negative* (-)</td></tr>
<tr><td>Original function $f(x)$</td><td>Increasing</td><td>Decreasing</td><td>Decreasing</td><td>Increasing</td><td>Increasing</td><td>Decreasing</td></tr>
<tr><td></td><td colspan="2">Max</td><td colspan="2">Min</td><td colspan="2">Min</td></tr>
<tr><td></td><td></td><td colspan="2">*Inflection Point*</td><td colspan="2">*Inflection Point*</td><td></td></tr>
</table>

When applying this table to graphs of position $x(t)$, velocity $v(t)$, and acceleration a$(t)$ the following guidelines will help:

1. A function is CONSTANT/HORIZONTAL ( $\leftrightarrow$ ) derivative is ZERO.
2. A function is DECREASING $\leftrightarrow$ derivative is NEGATIVE.
3. A function is INCREASING $\leftrightarrow$ derivative is POSITIVE.
4. A function is QUADRATIC $\leftrightarrow$ derivative is LINEAR.
5. A function is LINEAR $\leftrightarrow$ derivative is CONSTANT/HORIZONTAL.
6. A function is CONCAVE UP/DOWN $\leftrightarrow$ derivative is INCREASING/DECREASING

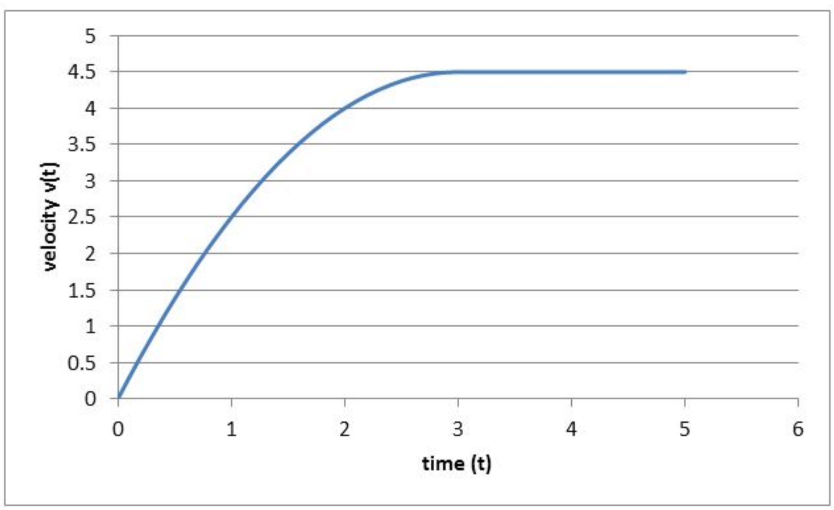
Thus for the following graph of the acceleration we can reconstruct the velocity as follows.




Let's first write down what we know and what this implies using the 6 equivalences above:

- a(t) the derivative is LINEAR from 0 to 3 ↔ v(t) the function is QUADRATIC from 0 to 3
- a(t) the derivative is POSITIVE from 0 to 3 ↔ v(t) the function is INCREASING from 0 to 3
- a(t) the derivative is DECREASING from 0 to 3 ↔ v(t) the function is CONCAVE DOWN from 0 to 3
- a(t) the derivative is ZERO from 3 to 5 ↔ v(t) the function is CONSTANT from 3 to 5

In order to draw a graph having these characteristics we need a starting point or initial condition. Assuming the initial velocity v0 = 0 we start our graph at the origin, changing this **initial condition** simply raises or lowers (shifts vertically) this shape determined by the conditions above:



**B. Faculty Development Workshop on Reasoning with Evidence**

The following agenda gives a sense of what is covered in a workshop on Reasoning from Evidence, aimed at engaging the campus community in a discussion on how QR can permeate the curriculum.

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**Reasoning from Evidence Workshop Agenda**

1. Welcome and Introductions
2. Lunch Conversation about our group and this workshop
3. Participant descriptions of evidence and argumentation in their disciplines
   a) Conversation
   b) White board notes in 3 columns:
      i. **R**easoning
      ii. **E**vidence
      iii. **A**rgumentation
4. Sample papers
   a) English Poetry and Dependency Ratios
   b) How do our categories for REA apply to these papers?
   c) Differences and Similarities between disciplines
5. Sample Rubrics
   a) AACU Critical Thinking Rubric [2]
      i. How does this relate to our notes?
   b) Carleton's Quantitative Engagement[3] rubric
      i. Simple yet powerful in changing culture!
   c) Bowdoin's 6 Questions in First Year seminars
      i. Looks familiar!
6. Wrap Up ☺

The link given to Numeracy Infusion Course for Higher Education (NICHE) is another great resource for QMaSC directors.

[2] http://www.aacu.org/value/rubrics/index_p.cfm?CFID=46004977&CFTOKEN=58030724

[3] http://serc.carleton.edu/NICHE/ex_qr_assessment.html